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Identifying and overcoming barriers to onsite non-potable water reuse in California from local stakeholder perspectives

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ABSTRACT

Onsite (a.k.a. decentralized) water reuse can reduce overall potable water demand and aid in meeting water reduction goals. In spite of clear benefits, onsite non-potable water systems (ONWS), specifically non-blackwater commercial systems, face many challenges that are preventing growth and expansion in California. This study utilized a technical advisory committee and a survey to identify the most significant challenges facing onsite water reuse systems, how these challenges affect ONWS stakeholders, and potential solutions at the state level. The given methods found that the most prevalent challenges hindering the growth of ONWS appeared to be the absence of a local regulatory program, system cost, poor access to training for regulators, and limited public education about alternate water sources. Survey results revealed several possible drivers for the existence of these challenges including that informational and training resources are not adequately disseminated to target groups. The study concluded that the creation of trainings for regulators, the development of an organization dedicated to onsite systems, expanded technology certifications, policy changes, and highlighting existing systems might help overcome the challenges hindering growth and allow for greater expansion of onsite non-potable water systems throughout California.

1. Introduction

In response to frequent droughts, mandatory water reductions, and the increasing demand on water and wastewater systems in California, onsite water reuse has gained attention as a way to meet changing needs and reduce potable water demand. Working in combination with centralized water and wastewater systems, onsite non-potable water systems (ONWS) have been shown to reduce overall potable water consumption and contribute to a sustainable water supply (Wilderer and Schreff, 2000; Mitchell, 2006). Onsite graywater reuse, for example, in a scenario that also included a centralized blackwater system, has been shown to reduce both potable water and electricity consumption by up to 49% for single-family applications (Jeong, et al., 2018). Under certain circumstances, decentralized systems can be more cost-effective and energy efficient than their centralized counterparts largely due to reduced transport distances and infrastructure requirements, and their ability to separate sources and treat to 'fit-for-purpose' levels as opposed to generic high level treatment (Onkal Engin and Demir, 2005; Nelson, 2005). Additionally, ONWS can be desirable as a means of increasing water security as water sources become increasingly strained and their uses regulated (Jonasson and Kandasamy, 2018)

In spite of the possible benefits of ONWS, uptake has been slow and many states lack clear regulations for these types of systems (Yu et al., 2013). Some potential reasons for this lag in growth is that local authorities may not have the necessary knowledge, are unwilling to regulate these systems, or they may be lacking the needed resources to do so. Additionally, there has been hesitancy on the part of some water and wastewater utilities to embrace alternate water sources due to public health concerns, potential loss of revenue, and reduction of wastewater and its ability to carry solids (Reeb, 2018). Other cited impediments include inconsistent graywater definitions, water quality requirements, and storage and irrigation restrictions (Yu et al., 2013).

Also referred to as decentralized water reuse, onsite reuse is defined as the "collection, treatment, and reuse of wastewater at or near the point of generation" (Crites and Tchobanoglous, 1998). Onsite reuse systems utilize alternate water sources, such as graywater, rainwater, stormwater, and blackwater, for non-potable applications such as cooling, toilet-flushing, industrial processing, irrigation, and others, thus all such systems can be referred to with the common name of *onsite non-potable water systems* (ONWS). The term *onsite reuse* refers to the main function of onsite non-potable water systems. For the purposes of this research, ONWS will be used in reference to commercial/industrial and non-blackwater systems since blackwater systems are regulated

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Table 1
Written resources focusing on regulation and implementation of onsite non-potable water systems.

Document	Producer	Funded by	Content
Step-By-Step Guide[1]	San Francisco Public Utilities Commission	US Water Alliance, The Water Research Foundation	Provides guidance to local regulators on how to develop an onsite non-potable water program.
Risk-Based Framework[2]	The National Blue Ribbon Commission	US Water Alliance, The Water Research Foundation	Supplies risk-based guidance for public health determinations for onsite non-potable water systems.
Guidebook for Implementing Regulations[3]	The National Blue Ribbon Commission	US Water Alliance, The Water Research Foundation	Gives guidance to local regulators on water quality criteria, standards, and best management practices for onsite non-potable water systems.
Utility Case[4]	The National Blue Ribbon Commission	US Water Alliance, The Water Research Foundation	Explains utility benefits and motivations to incorporating onsite non-potable water systems.
Practice Guide[5]	William J. Worthen Foundation, Urban Fabrick	William J. Worthen Foundation and others	Guides architects and building design professionals on incorporating onsite non-potable water systems into their projects.

[1] "Blueprint for Onsite Water Systems: A Step-by-Step Guide for Developing a Local Program" (2014).
[2] "Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water System" (2017).
[3] "A Guidebook for Developing and Implementing Regulations for Onsite Non-Potable Water Systems" (2017).
[4] "Making the Utility Case for Onsite Non-Potable Water Systems" (2018).
[5] "Onsite Non-Potable Water Reuse Practice Guide" (2018).

under longstanding state regulated Title 22 regulations and residential systems typically have lower water saving potential than commercial or industrial installations (Gauley, 2017).

To date, most research on the challenges facing water reuse has been focused on centralized recycled water systems and public opinion. This study takes a different approach, exploring the challenges specific to onsite systems from local stakeholder perspectives including regulating entities, system designers, consultants, and engineers. This research is necessary and timely as onsite non-potable water reuse is an emerging field for which guidance and regulation continues to be developed.

This study was undertaken to discern and understand challenges to widespread adoption of commercial onsite alternate water source reuse, and, more crucially, to uncover efforts to address these obstacles and inform future steps to meaningfully reduce these challenges. In order to accomplish these objectives, researchers convened a technical advisory committee and collected survey data, which resulted in: 1) a ranked list of the challenges facing specific groups and regions in California, 2) a description of knowledge dissemination methods that have been employed and how relevant individuals receive knowledge and resources, and 3) targeted, actionable solutions to address the challenges.

1.1. Background

Historically, water reuse in California has been predominately performed on the centralized level, but not without its share of difficulties and adversity (DWR, 2003). California, recognizing the probable benefit of using water recycling as a means to augment demands for freshwater, created the Recycled Water Task Force in 2001 to examine the potential of centralized water recycling as well as the obstacles (DWR, 2003). The task force identified that issues with public health, cost, public acceptance, and institutional barriers needed to be overcome in order to fully utilize recycled water for a full host of applications (Mills et al., 2004). In some instances these barriers, such as the absence of public acceptance, for example, were significant enough that they prevented projects from moving forward (Mills et al., 2004).

Since that time, progress has been made to address the list of impediments to centralized water recycling generated by the task force. A recent survey of centralized water reuse managers cited many positive drivers for their reuse program with only 26% citing negative perceptions for recycled water (Bischel et al., 2012).

In California, onsite non-potable water systems (ONWS) are regulated almost entirely by the California Plumbing Code (CPC), chapters 15, 16, and 16a (Alternate Water Sources for Nonpotable Applications, 2016; Nonpotable Rainwater Catchment Systems, 2016, and Non-potable Water Reuse Systems, 2016), which are interpreted and enforced at the local level. Currently, the CPC allows for the use of alternate water sources for both indoor and outdoor applications, but leaves water quality, treatment, monitoring and reporting requirements, as well as specific end uses, for the local regulatory authority to decide. However, if the alternate water source includes blackwater, detailed recycling requirements are found in Title 22, Chapter 3 of the California Code of Regulations (Water Recycling Criteria, 2014), which is regulated by regional water quality control boards using uniform statewide criteria.

Most water reuse is and has been performed on the centralized municipal level in part due to rigorous Title 22 requirements, such as daily coliform and continuous turbidity monitoring. The addition of non-potable reuse to the plumbing code over the past decade allowed other alternate water sources, such as graywater, to be regulated differently than blackwater and instead adhere to monitoring and reporting requirements as determined by the local authority having jurisdiction (AHJ).

To address the challenges facing ONWS, national organizations such as The Water Research Foundation and the US Water Alliance, which convened a National Blue Ribbon Commission for Onsite Non-Potable Water Systems, have created multiple documents targeted at regulators, utilities, and onsite design professionals and consultants. The William J. Worthen Foundation has also issued its own resource specifically for onsite water systems and designers. Table 1 lists several recently released documents targeting onsite water regulation and implementation. These resources, along with the recent passage of California Senate Bill 966 (2018), which aims to standardize water quality and monitoring requirements for onsite non-potable water reuse systems throughout the state, all aspire to increase standardization and expand awareness about ONWS.

Two regions in particular in California have made progress toward advancing onsite reuse. For example, San Francisco, a region where the city and the county share the same jurisdictional area, has created a dedicated Non-Potable Water program developed to provide permitting guidance to adopters of onsite systems and to require onsite water systems for new construction of buildings over 250,000 square feet as per local ordinance since 2015 (Onsite Water Reuse for Commercial, Multi-family, and Mixed Use Development Ordinance, 2012). As a result of this ordinance, San Francisco now has several buildings with non-potable water systems using rainwater, bay water, graywater, condensate, stormwater, and foundation drainage to achieve potable water reductions between 8% and 65% (SFPUC, 2018). Likewise, Los Angeles County has also developed its own Guidelines for Alternate Water Sources (Los Angeles County Department of Public Health, 2016), although there is a lack of coordination between the county and its cities since they operate independently. Outside of these regions, however, there are few locations in California with clear direction, leaving regulators and system designers and consultants alike unsure

how to proceed.

2. Methods

In order to assess the real challenges and barriers currently faced by onsite water systems in California, this study utilized a technical advisory committee and an electronic exploratory survey. Together these methods formed the basis for this study, illuminated the current state of beliefs and knowledge held by onsite non-potable reuse stakeholders, and guided the recommendations of appropriate solutions.

2.1. Technical advisory committee

A technical advisory committee (TAC), composed of professionals from different perspectives who are all actively involved with onsite water reuse in California, was created to offer insight and guidance for this project. Nine members participated in the meetings, six from the regulatory perspective and three engineers (a list of participants can be found in the acknowledgements section at the end of this article). The TAC met a total of three times. The first meeting was focused on establishing common challenges onsite reuse systems face and reviewing survey questions. The second meeting was designed to discuss solutions and changes that could be made to reduce or eliminate the listed impediments to ONWS. The final meeting was used to develop an action plan and review the overall findings of the survey and the research project as a whole. TAC input was critical to creating the final list of top ten challenges (Section 3.1), reviewing the survey, and developing the recommended solutions (Section 3.6) that came out of the survey results and are discussed in this paper.

2.2. Onsite alternate water source reuse survey

Generally, exploratory survey methods are used for new topics and when a survey population is difficult to identify (Shields and Rangarajan, 2013). Given the newness of this field and that many local regulatory programs have not been established, it was difficult to structure the survey so as to represent all current and prospective regulators and system design professionals. As such, this survey and its results were meant to provide new insight into the topic without necessarily enabling statistical inferences about the sector as a whole.

2.2.1. Survey description

An opt-in internet based survey was selected given its ease of distribution and low cost. The survey was composed of 12 questions sent out by email to individuals in California using Qualtrics software between August 21 and September 18, 2018. Survey questions were created based on TAC discussions and reviewed prior to piloting and full scale distribution. The survey provided standardized definitions at the beginning and asked respondents about their work affiliations and locations. Questions were related to their personal beliefs about ONWS, their knowledge of onsite reuse, their familiarity with existing resources, and their perception of challenges preventing the growth of ONWS.

The goals of the survey were to identify common challenges and barriers impeding onsite water reuse, assess existing efforts to address these challenges, and determine who is affected by these challenges and why these challenges exist. The information gathered through the survey was used, along with further research, to develop targeted solutions to the challenges. The results of the survey were filtered according to stakeholder group and location affiliation and resource familiarity so that different groups could be compared using a chi-square analysis to find significant differences between groups.

2.2.2. Recipient selection

Survey recipients were selected to represent the different stakeholder perspectives of onsite non-potable water reuse, including the regulatory side defined as city, county, and state regulators, and the system side, defined as system designers, consultants, and engineers. Email addresses for the regulators were found using publicly available websites for all cities and counties for which such contacts could be found (44 counties, 392 cities). Contacts for system-side entities were found by contacting publicly listed companies and individuals that work with onsite non-potable water systems for major cities in California (32 companies). Chain-sampling (a.k.a snowball sampling) was allowed: survey recipients were encouraged to pass the survey along to the most appropriate respondent within their agency as well as anyone else in their organization who might deal with onsite water reuse. This method is commonly employed for unknown populations and can add a degree of bias to the sample results (Heckathorn, 1997). The inherent bias produced by this method means those who were forwarded the survey were likely more knowledgeable and involved in onsite water reuse than if they had been selected randomly. As such, the actual knowledge and resource familiarity in this sector may be less than reported by this study.

3. Results and discussion

3.1. Challenges facing onsite non-potable water reuse

Ten common challenges preventing the growth of onsite non-potable water reuse were identified from discussions with the TAC. Following TAC review, researchers decided that while not an exhaustive list of all challenges faced by ONWS, the following are the most significant and universal issues in terms of preventing growth:

3.1.1. Absence of a knowledgeable and supportive local regulatory program

As outlined in Senate Bill 966 (2018), in order to permit an ONWS, a local non-potable water regulatory program must be created and a local ordinance passed. If there is no established regulatory program or the local regulators do not know how to appropriately permit and regulate onsite systems, interested parties in the area are blocked from moving forward with onsite systems.

3.1.2. Cost

Onsite systems can be expensive and are not always a cost-effective option for facilities. In general, cost is a function of other factors. Retrofitting versus installing ONWS in new construction, for example, has a significant impact on cost. Likewise, water rates, technology, and the market also play a role in determining the relative expense of systems.

3.1.3. Poor knowledge

A general lack of knowledge of alternate water sources is often associated with a lack of knowledge about reuse potential as well as appropriate applications. If individuals do not know about ONWS and related options, they are unlikely to install a system or consent to regulate it.

3.1.4. Negative public opinion

Water reuse has often been met with mixed public perception and concerns about health risks, particularly for indoor as opposed to outdoor use (Liu, 2006). If the public has adverse associations with alternate water sources, either due to health concerns or inconvenient requirements and operation, then public jurisdictions and prospective ONWS owners are less likely to embrace onsite water reuse practices.

3.1.5. Poor coordination between local jurisdictional authorities

Given the lack of clarity with regards to authorities having jurisdiction per plumbing code specifications, regulators outside of building departments are commonly overlooked or not consulted for new ONWS permits. This lack of coordination between regulators in localities where the building department alone issues permits often

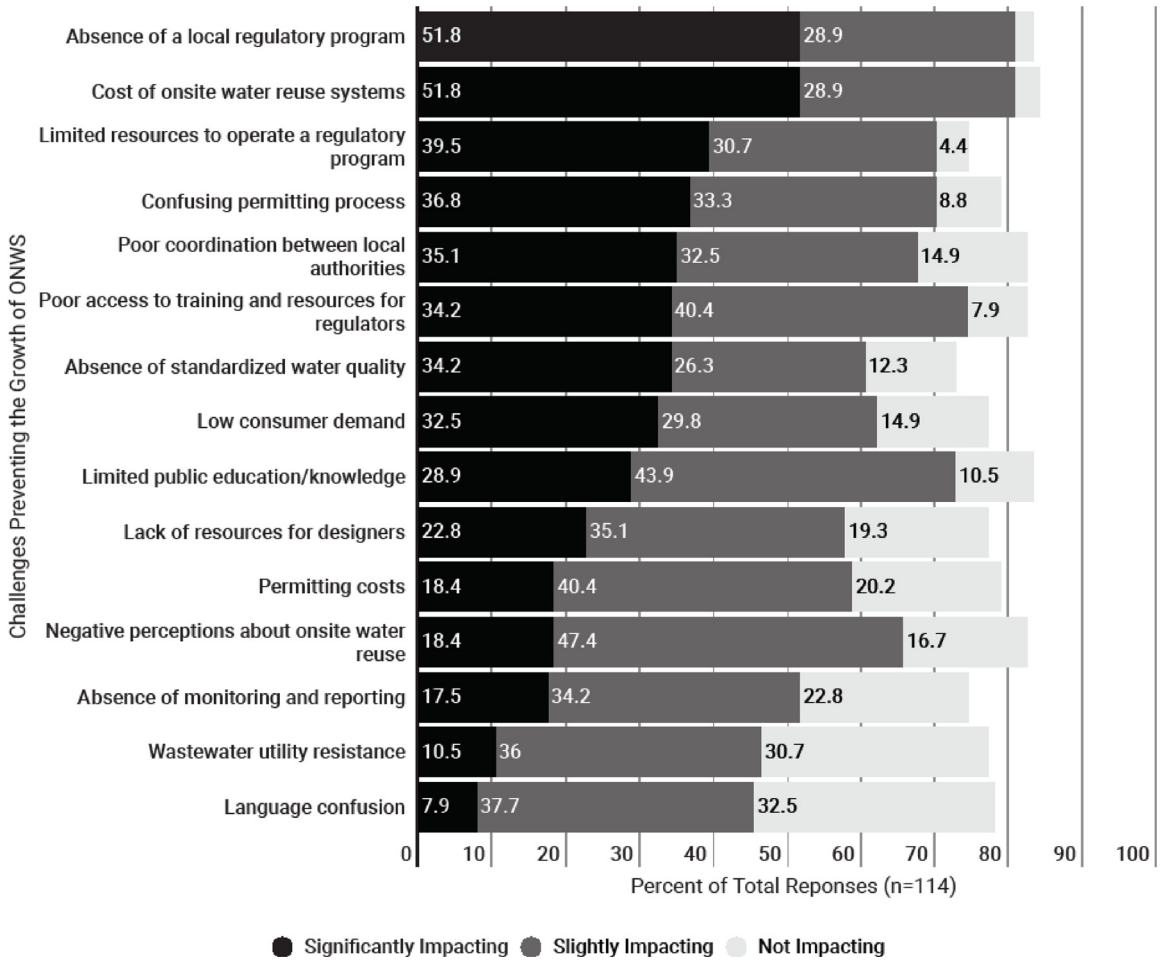

Fig. 1. Percentage of all survey respondents that found the listed challenges to be significantly, slightly, or not negatively impacting the growth of ONWS.

precludes the review and oversight environmental health agencies would provide if they were involved in the process. When roles are unclear, it can be difficult to discover the appropriate AHJ and navigate an ill-defined process.

3.1.6. Wastewater utility resistance

Some utilities have not embraced decentralized treatment for a variety of reasons, including concerns with reduced wastewater flows. In some areas, utilities may act as a strong lobbying force against decentralized reuse, impacting statewide legislation or their local jurisdiction.

3.1.7. Lack of support for program development

Creation of a local program to regulate ONWS requires not just knowledge about regulations, but the creation of water quality standards, program rules, inspection forms, monitoring and reporting practices, enforcement criteria, and more. Development of these internal documents and procedures requires knowledge building, person-hours, and funding, which can be in limited supply.

3.1.8. Lack of state standardized risk-based water quality criteria

Establishing appropriate risk-based standards for every source and potential non-potable application can be an onerous task for local authorities, but blanket requirements, such as NSF 350, can either neglect risk or make systems unnecessarily protective and prohibitively costly to operate.

3.1.9. Absence of monitoring and reporting requirements

Monitoring and reporting for ONWS are important in maintaining safe-systems and demonstrating system benefits at both individual and aggregated regional levels, all of which are critical for positive public opinion. If not selected appropriately by the local regulator, however, monitoring requirements can become a significant operating burden that prevents the implementation of a system.

3.1.10. Lack of resources for ONWS designers

In most regions, there is little support or direction provided for the design of onsite non-potable water reuse system. The plumbing code is itself mostly limited to restrictions and for many specifications, such as water quality, it leaves the determination up to the local AHJ. System designers may need to identify the correct local authority, if one exists, and assertively seek answers about requirements.

3.2. Survey responses

The survey was sent to approximately 550 recipients: about 200 opened and began the survey and 114 completed and submitted the survey. The survey results presented in the following sections are based on these responses. Of the total respondents, 52% identified as regulators at varying levels (26% city, 17% county, 5% state, and 4% unidentified regulator); 40% identified themselves on the system side, often within multiple categories (i.e., system designer, installer); and 8% reported themselves as 'other', including responses from professionals representing water utilities, non-profits, the public education realm, and academia. Spatially, 67% of California counties were represented in this survey, however, a large number of respondents were associated with Sonoma (n = 19), Santa Clara (n = 13), San Francisco (n = 12), or Los Angeles (n = 11) county.

3.3. Perceived challenges

The 10 challenges presented in Section 3.1 were included in the survey, but in some cases were broken apart, for instance, cost was split into the cost of permitting and the cost of the system itself. The survey asked respondents to categorize the challenges as significantly impacting, slightly impacting, or not at all impacting the growth of ONWS in California. A 'no response' was also available. Fig. 1 depicts the full results for all respondents. The two most significant challenges reported were the cost of the systems themselves and the absence of a knowledgeable and supportive local regulatory program, with over 80% of respondents claiming either significant or slight impacts to growth. While found to be less impactful, a large percentage of total respondents also believed that poor access to training and resources for regulators and limited public education are having a negative impact on the growth of onsite reuse.

3.3.1. Ranking by affiliation

For the purposes of determining if these challenges were perceived similarly by regulatory and the system-side respondents, the results from Fig. 1 were filtered according to affiliation (i.e., regulatory or system side) to determine how they compare (see Fig. 2). Fig. 2 lists the challenges in the same order as Fig. 1, but separates the percentages for the two groups and includes the p-values based on a chi-squared analysis comparing the responses from the two groups.

As evidenced by a statistically significant p-value of less than 0.05, five negative impact beliefs were linked to whether or not a respondent identified as regulatory or system side: the absence of a local regulatory program, confusing permitting process, lack of resources for designers, permitting costs, and negative perceptions about water reuse. Results demonstrated that each group was more likely to believe that challenges outside of their scope are having a negative impact. For example, stakeholders from the system side were more likely to believe that permitting concerns, such as a confusing permitting process and permitting costs, are the reasons for slow uptake of onsite reuse. Conversely, regulators were more likely to blame the lack of resources for designers and negative public perceptions.

3.4. Possible challenge drivers

To determine the underlying causes of these challenges, with the ultimate goal of recommending effective solutions, the online survey also asked respondents about their beliefs, knowledge, and resource familiarity. Responses were explored to better understand the sources of the challenges listed in Section 3.1. Results are presented in the following sections.

3.4.1. Beliefs about onsite alternate water source reuse

3.4.1.1. Negative beliefs. The greatest disparity between regulatory and system-side respondents was found in their negative beliefs as shown is Fig. 3, numbers 1–7. Regulators were found to hold more negative perceptions than the system side, especially for the beliefs that ONWSs are a health risk, difficult to manage, and not aesthetically pleasing. In spite of these differences, the fraction of all respondents that held negative beliefs about ONWS was low relative to positive beliefs, at less than 40% for all cases. This indicates that while there may be some resistance to ONWS from the regulatory side due to management concerns, for example, most negative beliefs were not commonly held among those responding.

3.4.1.2. Positive beliefs. With regard to two of the largest potential benefits of ONWS, numbers 8–9 in Fig. 3, both regulatory and system-side respondents believed that indoor alternate water source reuse reduces potable water demand, but over twice as many respondents from the system side as compared to the regulatory side believed it can reduce overall energy consumption. This shows that while both sides believed there are benefits to be had by installing onsite systems, the system side held this belief more strongly than the regulatory side.

3.4.1.3. Inaccurate beliefs. The final three beliefs, numbers 10–12 listed in Fig. 3, were held by a percentage of both regulatory and system-side professionals, but are not necessarily true statements. Number 10, the belief that alternate water sources can be used for potable applications is not true in California given current regulations, however, nearly 24% of system-side respondents believed this to be true. The truth for numbers 11 and 12 regarding alternate water sources and applications depends on what local area jurisdictions decide to permit. While almost 30% of regulators believed only shower and laundry water can be reused indoors, rainwater, foundation drainage, and water from non-kitchen sinks are all acceptable alternate water sources per the CPC. Similarly, while over 45% of both regulators and system side respondents reported that toilet flushing and cooling are the only allowed indoor applications, other indoor applications such as industrial processing and washing are allowed. Both these results suggest that at least some fraction of those dealing with alternate water sources are either located in areas that restrict their use or they do not understand the full range of possibilities.

These survey results imply generally that those who regulate or implement systems, may adhere to inaccurate beliefs. Such misconceptions might result in overprotective requirements, limited source options, and restricted applications, all of which would contribute to the challenges listed in Section 3.1 and reduce beneficial outcomes.

3.4.2. Knowledge and resource reception

While the resources listed in Table 1 are intended to address challenges facing ONWS, their impact depends on whether they reach the appropriate audience. Findings from the survey indicate that, in many instances, these resources are either not reaching their targeted audience or are not being read.

Fig. 4a shows reported familiarity with the resources listed in Table 1. In all cases, greater than 50% of respondents had never heard of the resources, and, in all cases, less than 20% had read any. Breaking this down further by respondent affiliation, Fig. 4b shows that of those who had read or skimmed the resources, most affiliated themselves with the system side. Documents such as the "Step-By-Step Guide" (2014) and "Guidebook for Implementing Regulations" (A Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems), which are meant specifically to help regulators create local programs, were being skimmed or read about twice as often on the system side as the regulatory side.

Regulators may not be receiving these resources due to dissemination methods. Currently, the resources listed in Table 1 are posted online and discussed at conferences and webinars. Looking at Fig. 4c, only about 40% of regulators get information about ONWS from conferences and a sizable fraction, 30.5%, do not receive any information at all. When trying to access certain audiences, it is critical to understand how they receive and digest information.

Many of the challenges listed in Section 3.1 might arise from a lack of knowledge and understanding of alternate water sources and ONWS. As a means to determine if this is the case, the survey asked respondents to report their level of familiarity with ONWS. Seventy percent of system-side respondents believed themselves to be very knowledgeable about onsite non-potable reuse as opposed to only 38% from the regulatory side. This knowledge disparity might explain why more regulators than system-side respondents held negative beliefs as discussed in Section 3.4.1 and why regulators on the whole found the listed challenges, as shown in Section 3.3.1, to be more impactful than the system side believed them to be. This gap in knowledge on the regulatory side is understandable given that, for many local regulators, their primary job description encompasses many roles, whereas the system side's primary focus is on water system design, development, and operation. In order to overcome this knowledge gap, resources have

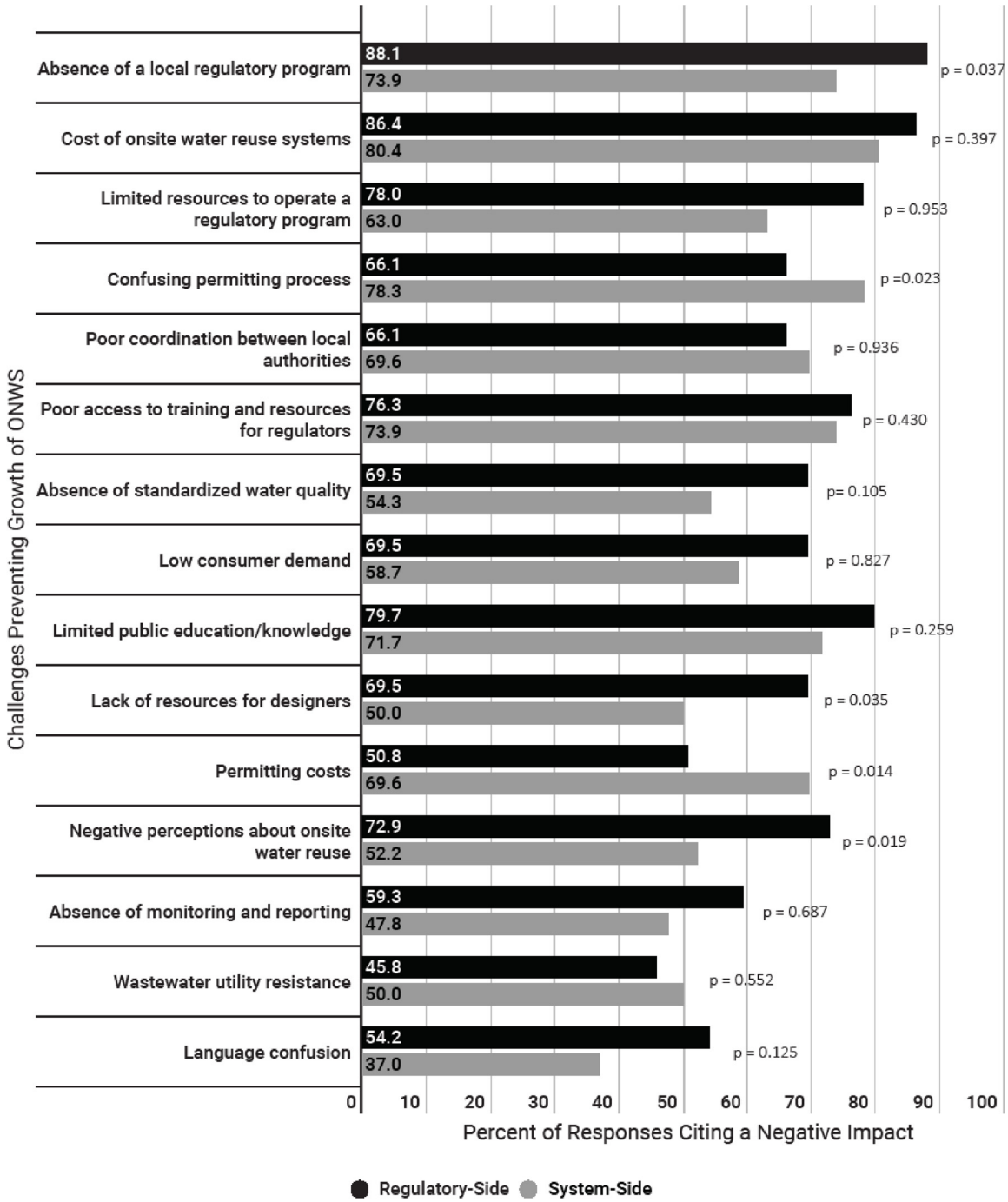

Fig. 2. Percentage of regulatory and system-side survey respondents that believed a specific challenge was preventing growth of ONWS.

been created that specifically target regulators, but, as seen in Fig. 4, in many instances these resources are not reaching or being read by their targeted audience.

To determine the impact that the resources have when they are read, Fig. 5 shows the percentage of respondents that had read at least one of the resources from Table 1 as compared to those that had not read any of the resources — in terms of their valuation of ONWS, their self-reported knowledge, and their inaccurate beliefs. Stakeholders that had read at least one resource were more likely to believe that onsite reuse is extremely important for California's future. Additionally, those who had read the resources considered themselves more knowledgeable than those who had not, with a larger percentage ranking their knowledge higher than their counterparts on a 1 out of 10 scale. What is not apparent from these results is cause and effect: whether those who considered themselves very knowledgeable were more likely to read these resources, or those who had read these resources were more likely to consider themselves knowledgeable.

Interestingly, those who read at least one resource were more likely to hold inaccurate beliefs than those who had not read any. In the case of the belief that alternate water sources can be used for potable applications, this may be due to efforts in California to implement direct potable reuse, which though not yet legal, has made progress (Harris-Lovett et al., 2015). The belief that toilet flushing and cooling are the only allowable indoor applications could follow from the fact that these applications are the most frequently mentioned when discussing indoor reuse. Without further analysis definitive causes cannot be known.

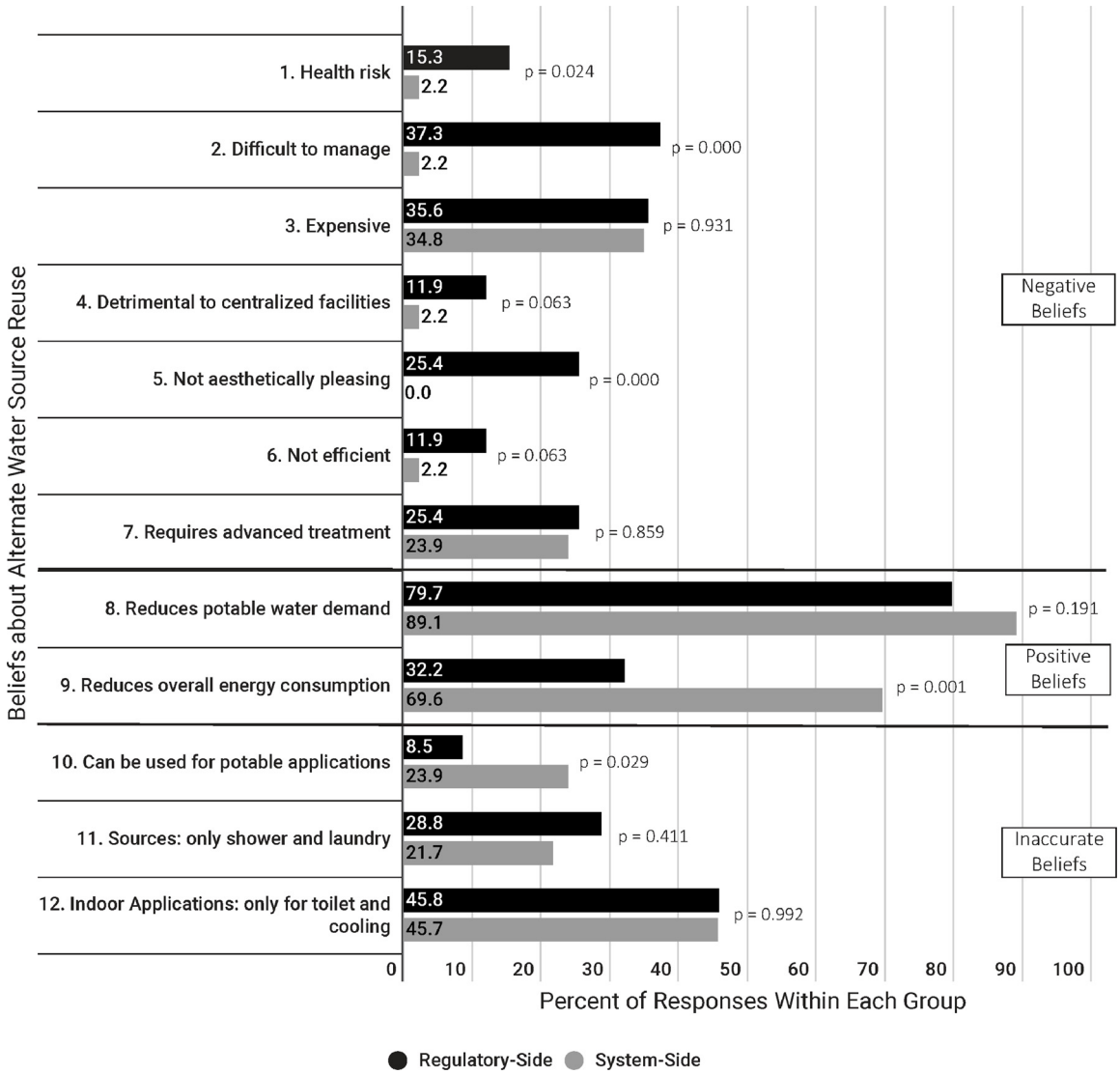

Fig. 3. Positive, negative, and inaccurate beliefs about onsite use of Alternate Water Sources (excluding blackwater).

3.4.3. Presence or absence of a local program – what is the difference?

To further understand the impact of challenges, two areas of California were compared, one with developed non-potable water regulatory programs and the other without. San Francisco and Los Angeles counties were considered together since both have developed non-potable water programs. On the other side, Sonoma and Santa Clara counties were investigated together since both, per phone interviews, have notable demand from entities such as technology companies and wineries, but lack developed non-potable water programs and permit guidance. These four counties represented the largest number of respondents with an even spread of respondent types (San Francisco and Los Angeles: n = 20, system 65%, regulator 20%, other 15%; Sonoma and Santa Clara: n = 28, system 61%, regulator 25%, other 14%).

Notably, there was a difference in self-reported knowledge between the two regions. In the counties with a developed local program, 90% of respondents considered themselves to be very knowledgeable about ONWS as opposed to 61% in the regions without a dedicated local regulatory program ($p = 0.024$). When comparing resource familiarity, 45–60% of respondents from the areas with a program had read or skimmed the resources from Table 1, whereas between 15–42% from the areas without a program had read or skimmed the same resources ($p = 0.007$-0.242). Considering the difference in knowledge and resource familiarity, there was also a difference in how each region ranked the challenges with the top five from counties with a local program being (1) Confusing Permitting Process (100%), (2) Absence of a Local Program (85%), (3) Poor Coordination between AHJs (85%), (4) Cost (80%), and (5) Limited Resources to Operate (80%). In the localities without a regulatory program, the top five challenges were ranked somewhat differently as (1) Cost (82%), (2) Absence of a Local Program (79%), (3) Confusing Permitting Process (78%), (4) Negative Public Perceptions (79%), and (5) Poor Knowledge (75%).

The top challenges in each region show that even in areas where local programs exist, respondents felt like the absence of a local program and a confusing permitting process were preventing growth throughout the state. In places such as Sonoma and Santa Clara counties — where established non-potable water programs do not exist and there is less familiarity with ONWS and less exposure to resources — challenges such as negative perceptions about onsite water and limited education were deemed more impactful than they were in places with more familiarity and knowledge. This indicates that challenges can be location specific and effective solutions to these challenges must reflect this.

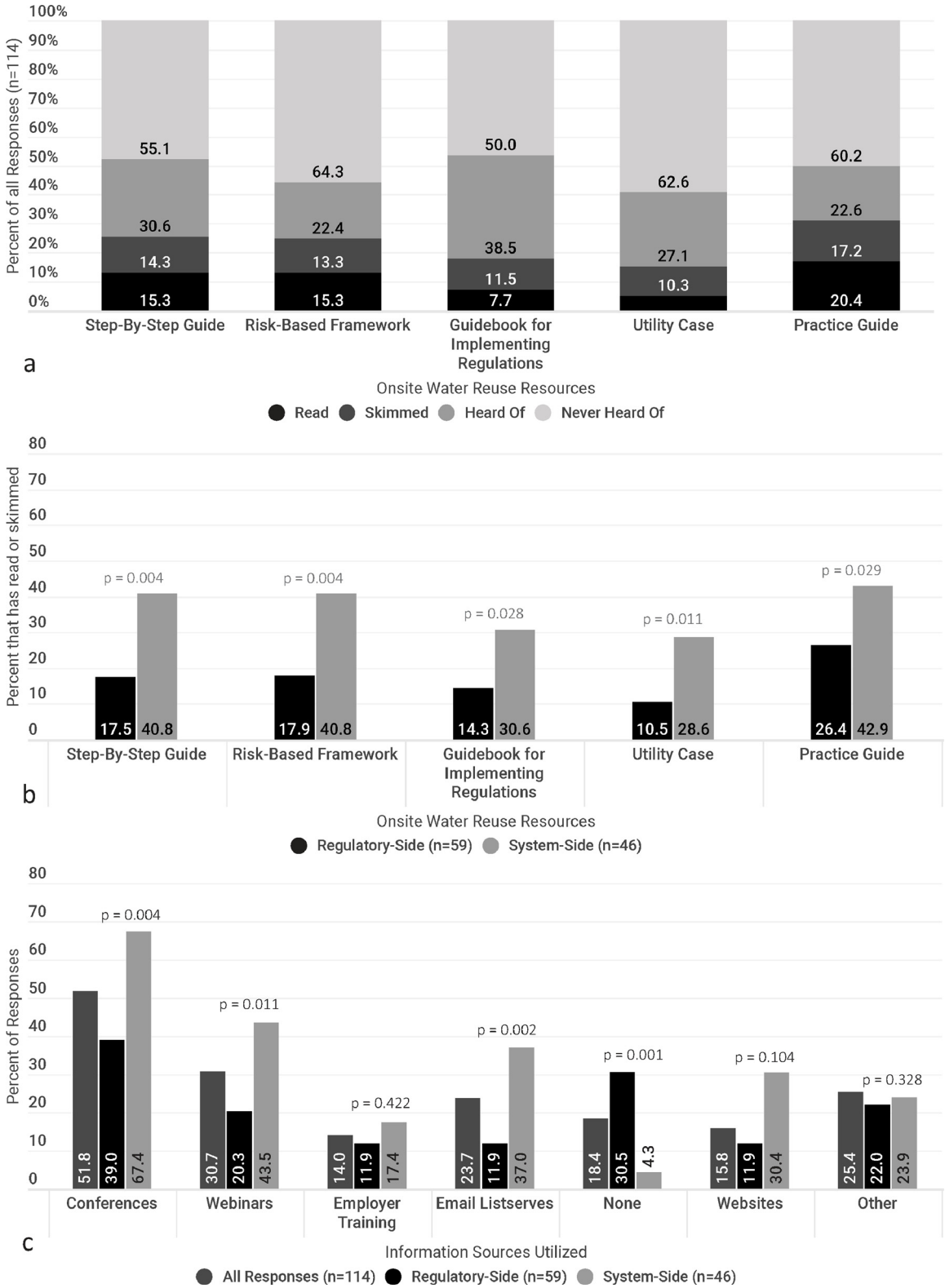

Fig. 4. Resource familiarity and information sources utilized reported by individual resources and respondent affiliation (i.e. system or regulatory side).

3.5. Proposed solutions

Given the findings from the survey and the relationships between the challenges, several solutions were formulated in consultation with the TAC to address the top challenges, acknowledging the current state of knowledge and beliefs.

3.5.1. ONWS dedicated organization

Currently, existing resources for ONWS are housed in various locations, do not include accompanying trainings, and are not specific to California. If an organization, or a branch thereof, could fill the role of a dedicated hub, it would address several of the challenges affecting ONWS growth. For example, some functions could include housing

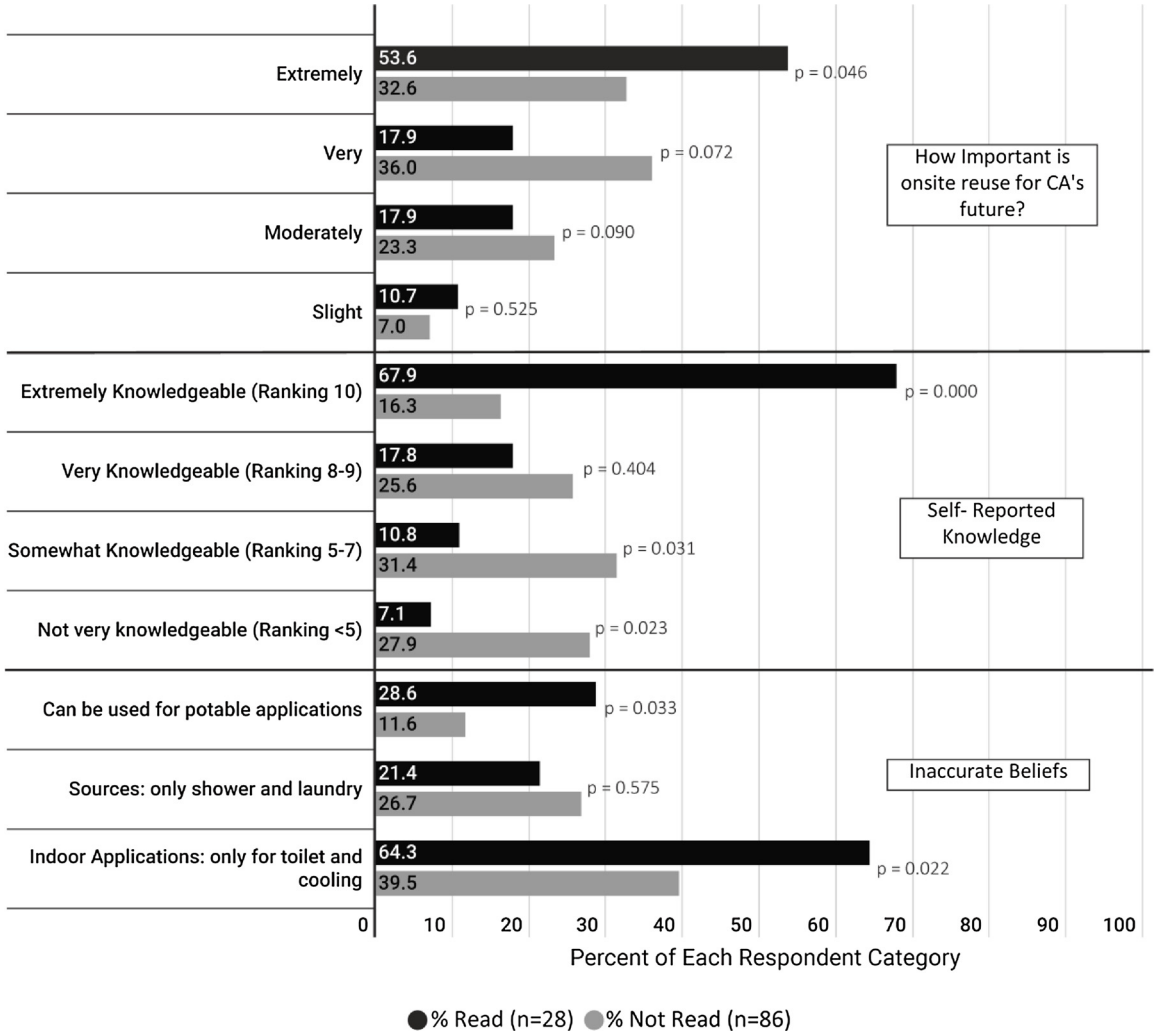

Fig. 5. Beliefs and self-reported knowledge for the respondents that had read at least one of the targeted ONWS resources and those that had not read any of the resources.

resources, responding to questions, conducting training and certifications, and acting as a clearinghouse. Such activities would help to clarify the permitting process, make resources more accessible, and support the creation of local regulatory programs. Housing all of these activities in the same organization would send a clear and consistent message as well as increase the effectiveness and efficiency of resources and efforts aimed at supporting the growth of ONWS. This entity would, ideally, utilize existing organizations so as to leverage work that has already been accomplished. The success of this institution would depend on a diverse stakeholder group to represent many perspectives. Two specific functions this organization should facilitate are regulator trainings and technology certification.

3.5.1.1. Regulator trainings. A recurring highly listed challenge for both regulators and the system side alike was the lack of training and resources for regulators. Fig. 4c demonstrates that most regulators are not getting their resources from websites or employers, nor are they reading existing resources, as per Fig. 4b, indicating that a different approach is needed. Direct in-person trainings could relate the content of existing resources as well as emerging guidance from SB 966 (2018) in ways that would be readily accessible to regulators. In order to support this training and overcome the major hurdle of funding, trainings should be designed to qualify for continuing education units (CEUs) such that staff development funds could be utilized. Working within an existing training system would make the expansion of onsite non-potable water knowledge as seamless as possible.

Shadow programs are another type of regulator training identified by the TAC as having been previously successful in their sector. Allowing regulators to see how another region or project is operating could provide important knowledge to less experienced regions as well as increase their confidence in reviewing their own systems.

Overcoming this challenge with more diverse ONWS training resources would improve regulator knowledge and help support program development, thus helping to overcome another highly ranked challenge, the absence of a local program.

3.5.1.2. Technology certification. Cost was the second highest ranked challenge significantly impacting the expansion of onsite water use and driving down demand (see Fig. 2). One reason these systems are considered expensive is due to the limited number of technologies competing in the ONWS market. Currently, only a handful of packaged technologies meets NSF 350 or Title 22 water quality standards (NSF Certified Wastewater Treatment Units, 2015). Creating certifications that match the risk-based water quality standards to be developed by the California State Water Resources Control Board under SB 966 (2018) would give ONWS stakeholders and regulators confidence in technology selection, preventing costly and overprotective requirements. Encouraging greater certification would also expand the options for prospective system owners, driving competition and eventually lowering costs. As an added benefit, increased certification

to match risk-based standards would also help address negative public perceptions with ONWS such as health risk.

3.5.2. Policy changes

Perhaps the most impactful solution to the listed challenges would be the creation of policies that require ONWS for new construction of a certain size or for certain alternate water sources, especially in regions where no centralized water recycling option exists. Implementation of such policies would not only catalyze the creation of local programs, it would also create demand and open up the ONWS marketplace to new innovation and competition thereby driving down cost. Alternatively, as a more gentle introduction, dual plumbing stub outs in new construction that enable the reuse of non-potable water indoors could be added to the CALGreen checklist (California Code of Regulations Title 24, Part 11) as an optional item that could eventually be required. These policies have been implemented in a few localities, however, state level change may be difficult given unique regional and county level challenges across California. As existing challenges are overcome, policy development might become an appropriate next step.

3.5.3. Highlight positive examples

While not the highest ranked among impactful challenges, negative public perception and limited knowledge were considered by many to have at least a slight negative impact on the uptake of ONWS as per Fig. 1. While increased education about ONWS has been shown to do little to improve public attitude, drawing attention to existing successful implementations in local areas can produce more favorable opinions towards the use of alternate water sources (Hui and Cain, 2018). From the survey, the most cited reason for low demand was an unfamiliarity with alternate water sources and the concept of reuse. Highlighting successful systems not only expands awareness of ONWS but can also improve public opinion and drive demand. This could be achieved via tours of existing systems, case study documents, or informational displays in lobbies and waiting areas about the water and energy savings of systems in the area.

3.6. Recommendations for future research

As advances are made in the ONWS field, future research could be conducted to more fully quantify the impact and opportunities of onsite systems. This study examines beliefs of regulators and the system side, but research assessing the opinions and beliefs of the general public towards alternate water sources and onsite reuse, especially in areas without developed non-potable water programs, could help expand understanding of ONWS challenges. As challenges are removed and more ONWS are installed, data could be collected from monitoring efforts that allow for the quantification of water and energy savings for existing and projected ONWS. This could then improve understanding of the impact these types of systems may have toward meeting water and energy goals, serving to not only support the expansion of ONWS but also provide data that could be relevant to regions outside of California.

Additionally, this study focused on onsite reuse in a somewhat general way and did not separate out the individual alternate sources such as rainwater or graywater. ONWS stakeholders may have different views and experiences with different alternate water sources, which could be a valuable topic for future research focusing on specific challenges for different types of reuse systems.

While this research was largely focused on California and its specific regulations, similar results might be expected in other regions in the United States and the rest of the world. High ranked challenges such as cost, for example, are likely to be experienced in any location where these types of systems are implemented. In order to expand the benefits of ONWS beyond California, additional research to assess the challenges faced by other regions with different regulations could be enlightening.

4. Conclusion

Consultations with a technical advisory committee and a survey indicate that onsite non-potable water systems face many challenges that are preventing growth and uptake in California. The most significant challenges uncovered were the absence of a local regulatory program, the cost of onsite systems, limited public knowledge and education, and a lack of resources for regulators. These challenges appear to be driving not only low demand for these systems, but also making it difficult for potential system installers and owners to navigate a confusing permitting process.

Survey results also showed that while many respondents on the system side, including designers, consultants, and engineers, were very familiar with onsite systems, many regulators had less familiarity. While resources exist to help address these challenges and provide guidance and knowledge to regulators, these resources are either not distributed effectively or the information they contain is not being conveyed. Even when such resources reached an appropriate audience, it appeared they were not being read.

If the benefits of ONWS are to be realized, these challenges need to be overcome with targeted solutions that reflect the present reality. Given the current challenges and the state of knowledge and beliefs about ONWS, several solutions could be implemented that would reduce the difficulties facing onsite systems, including the creation and delivery of trainings for local regulators, the formation of a dedicated onsite non-potable water system organization, increased certification of onsite water technologies, policy changes, and a focus on existing successful systems.

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Appendix A. Survey

Indoor Commercial Alternate Water Source Reuse Survey

The results of this survey will help assess the challenges and barriers preventing the uptake of onsite indoor non-potable water reuse in California. Understanding the challenges facing onsite reuse is the first step to finding solutions that ease regulation and permitting of alternate water sources, while protecting public health and water system reliability. Thank you for your participation. Your response could have a significant impact on the future of water reuse in California. *The following terms are used in this survey as defined below.* **Definitions:**

Alternate Water Source*- non-traditional water source such as graywater, rainwater, stormwater, foundation drainage, cooling water, and industrial process water. *For the purposes of this survey, although typically included, blackwater is excluded in the definition of alternate water source since black water is regulated differently than other alternate water sources and is often associated with a higher level of risk.

Blackwater - water that contains any amount of wastewater from toilets, kitchen or utility sinks, or dishwashers. ***Graywater*** - wastewater that does not contain contamination from biological waste. Common sources are washing machines and showers. ***Onsite Non-Potable Water Reuse*** - (also referred to as Onsite Water Reuse) use of alternate water sources for non-potable applications in close proximity to where the water was collected or generated. Example: Collecting rainwater, treating it, and using it onsite to flush toilets. ***Indoor Commercial Water Reuse*** - water reuse for indoor applications (i.e. non-irrigation) such as toilet flushing, cooling, and washing at commercial facilities (i.e. non-residential). Example: Using treated cooling tower water to wash equipment room floors. ***"Indoor Commercial Alternate Water Source Reuse"*** - a type of onsite non-potable water reuse that uses an alternate water source at a commercial facility for non-irrigation applications.

"Indoor Commercial Alternate Water Source Reuse" is the target of this survey and the focus of the following questions.

1 Which category best describes you? Select all that apply.

☐ Regulator, Department of Public/Environmental Health
☐ Regulator, Department of Building Inspection/Permitting
☐ Regulator, other (please specify)
☐ Onsite non-potable water system designer
☐ Onsite non-potable water system installer
☐ Onsite non-potable water system operator
☐ Onsite non-potable water system owner
☐ Prospective onsite non-potable water system owner
☐ Other (please specify)

2 In what regions of California are you located and/or have alternate water source affiliation. Write all that apply separated by commas.

☐ County/counties:
☐ City/Cities:

3 How familiar are you with alternate water source reuse for non-irrigation applications?

0-10

4 In your opinion, how important is "Indoor Commercial Alternate Water Source Reuse" for California's future?

Extremely important
Very important
Moderately important
Slightly important
Not at all important

5 Which of the following resources about onsite water reuse have you heard of? How many have you skimmed? Read?

☐ Never Heard of
☐ Heard of
☐ Skimmed
☐ Read

- Blueprint for Onsite Water Systems: A Step-By-Step Guide for Developing a Local Program to Manage Onsite Water Systems
- Risk-Based Framework for the Development of Public Health guidance for Decentralized non-Potable Water Systems
- A Guidebook for Developing and Implementing Regulations for Onsite Non-Potable Water Systems.
- Making the Utility Case for Onsite Non-Potable Water Systems.
- Onsite Non-Potable Water Reuse Practice Guide
- Water Savings and Financial Benefits Associated with Single-Family Package Graywater Systems
- How do you learn about "Indoor Commercial Alternate Water Source Reuse" regulations, new research, and/or resources? Select all that apply.

☐ Conferences
☐ Webinars
☐ Employer Training
☐ Email Listserves, specify
☐ Websites, specify
☐ Other, specify
☐ None, I don't receive any information

7 Which statements about "Indoor Commercial Alternate Water Source Reuse" (excluding blackwater), such as graywater, do you believe are true in California? Select all that apply.

☐ Poses a significant health risk.
☐ Difficult to manage.
☐ Systems are expensive.
☐ Detrimental to centralized treatment facilities.
☐ Not aesthetically pleasing (odor and appearance).
☐ Not efficient.
☐ Requires advanced treatment.
☐ Can save water by reducing overall potable water consumption.
☐ Can reduce overall energy consumption.
☐ Can be used for potable applications.
☐ Can only be done with water from showers and laundry machines.
☐ If indoors, it can only be used for toilet and urinal flushing and cooling.
☐ None of the above are true.
☐ Others, specify.

8 What challenges/barriers do you believe California agencies regulating "Indoor Commercial Alternate Water Source Reuse" face? Check all that apply.

☐ Absence of state standardized water quality requirements.
☐ Few informational resources about how safe systems should be designed.
☐ Deficiency of technical knowledge.
☐ Poor access to information about how to create a regulatory program.
☐ Lack of trainings on how to regulate indoor reuse.
☐ Limited resources to operate a regulatory program (staff, financial, etc.)
☐ Low consumer demand for indoor commercial water reuse systems.
☐ Language confusion (inconsistent definition of terms).
☐ They are not facing any challenges.
☐ I do not know.
☐ Other, specify.

9 What challenges/barriers do you believe potential "Indoor Commercial Alternate Water Source Reuse" designers, installers, owners, and/or operators face? Check all that apply?

☐ Lack of informational resources about the permitting process.
☐ Permitting costs.
☐ Water reuse system costs.
☐ Few information resources about how to design a safe system.
☐ Unclear or inconsistent information on what is required of onsite water reuse systems (i.e. Water Quality, Monitoring, Labeling, Cross-Connection Control, etc.)

☐ Negative perception about non-potable water (the "yuck factor').
☐ Absence of a knowledgeable local regulatory program that is able and willing to permit onsite water reuse systems.
☐ Low consumer demand for indoor commercial non-potable water reuse.
☐Language confusion (inconsistent definition of terms).
☐ They are not facing any challenges.
☐ I do not know.
☐ Other, specify.

10 What challenge and barriers are having a negative impact on the widespread implementation and uptake of "Indoor Commercial Alternate Water Source Reuse" systems in California?

Drag and drop each potential challenge into its impact category (Significant Negative Impact, Slight Negative Impact, Not Impacting)

- Low consumer demand for onsite water reuse systems.
- Cost of onsite water reuse systems
- Absence of state standardized water quality requirements.
- Few resources about how a safe system should be designed
- Absence of a knowledgeable local regulatory program that is able and willing to permit onsite water reuse systems.
- Poor access to resources or training about how to create a regulatory program to permit onsite water reuse systems.
- Confusing permitting process.
- Limited resources to operate an onsite water reuse regulatory program (ex. financial support and person-hours).
- Permitting costs.
- Negative perceptions about onsite water reuse (the 'yuck factor').
- Wastewater utility resistance
- Absence of monitoring and reporting requirements.
- Poor coordination between local authorities such as Public Health and Building Inspection.
- Limited public education/knowledge about alternate water sources.
- Language confusion (inconsistent definition of terms).
- Other, explain.
- In your opinion, why is there a low consumer demand for "Indoor Commercial Alternate Water Source Reuse" (excluding blackwater)? Select all that apply.

☐ It is not considered safe or sanitary.
☐ The systems are expensive.
☐ Operation of an onsite water reuse system is expensive.
☐ People do not know what alternate water sources are.
☐ People do not know that alternate water source can be reuse.
☐ The permitting process is difficult.
☐ Maintaining and operating onsite water reuse systems are inconvenient.
☐ I do not know.
☐ Other, specify.
☐ There is not a low demand for indoor commercial alternate water source reuse.

12 Are there any additional comments or clarification you would like to make about any of the previous questions?

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